MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2017/2018

EME4016 – HEAT TRANSFER
(ME)

12 OCTOBER 2017
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question Paper consists of five pages including the cover page.
2. Answer ALL four questions. Each question carries 25 marks and the distribution of the marks for each question is given in brackets [ ].
3. Write all your answers in the Answer Booklet provided.

Question 1

(a) Derive from first principles an expression for the thermal resistance of a spherical shell. Begin by applying Fourier law to a spherical shell. Sketch the diagramme, indicating the location of the origin and the direction of the axis.

[5 marks]

(b) A spherical hollow sphere is made of aluminium with thermal conductivity 200 $W/m\cdot℃$. The inner radius is 2 cm and the outer radius is 6 cm. The inner surface is kept at a uniform temperature of 100 ℃, and the outside surface dissipates heat by convection with a heat transfer coefficient of 80 $W/m^2\cdot℃$ into ambient air at 20 ℃. Determine the outside surface temperature of the sphere and the rate of heat flow from the sphere. Use the thermal resistance concept.

[10 marks]

(c) A spherical shell contains heat dissipating components, and at a particular instant the temperature distribution in the shell is known to be of the form

$$T(r) = \frac{C_1}{r} + C_2,$$

where C_1 and C_2 are constants.

(i) Are the heat transfer conditions steady or unsteady?

(ii) How do the heat flux and heat rate vary with radius?

[10 marks]

Note: (1) The thermal resistance of a spherical shell is given by

$$R_{th} = \frac{1}{4\pi k}\left(\frac{1}{r_i} - \frac{1}{r_o}\right),$$

where k is the thermal conductivity of the solid, and r_i and r_o are the inner and outter radii of the shell, respectively.

(2) One general form of the conduction equation is

$$\frac{1}{\alpha}\frac{\partial T}{\partial t} = \nabla^2 T + \dot{q}/k,$$

where $T(\vec{r}, t)$, and other symbols have their usual meanings.

In 1-D spherical coordinates, take $\nabla^2 T = \frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{dT}{dr}\right)$.

Continued...

Question 2

(a) State Stefan-Boltzmann's law in equation form, explaining all symbols and give a consistent set of units for each parameter represented by the symbol.

[4 marks]

(b) A cubical room 2 m by 2 m by 2 m is heated through the floor by maintaining it at a uniform temperature T_1 = 250 K, while walls and the ceiling are at 200 K. Assume that the floor has an emissivity 0.9 and the walls and the ceiling have emissivity of 0.6.

(i) Find the heat loss from the floor.

(ii) Draw the thermal circuit for this problem, labelling all nodes and resistances with a consistent notation.

[15 marks]

(c) Explain with a diagramme how a specular-diffusing surface can be analysed in radiation exchanges. Use the example of exchanges among 4 walls in a square room, where one of the walls is specular-diffusing, and the other 3 walls are diffusing only.

[6 marks]

Note: Take the Stefan-Boltzmann constant to be $5.67 \times 10^{-8}\ W/m^2 \cdot K^4$.

Continued...

Question 3

(a) Write down the full name, the definition in terms of other parameters, and the physical significance for each of the following dimensionless parameters: *Nu*, *Re* and *Pr*.

[9 marks]

(b) Calculate the heat transfer from the roof of a vehicle assumed to be a flat surface 2 *m* long (along the movement) and 1 *m* wide, when the vehicle is travelling steadily at 10 *km/h* in still air. The roof surface temperature is 320 *K* while the air temperature is 300 *K*. Assume only heat convection. The overall relations for forced convection over a horizontal flat surface are:

For laminar flow ($Re < 5 \times 10^5$), $Nu_L = 0.664 {Re_L}^{0.5} Pr^{1/3}$

For mixed flow (laminar plus turbulent),

$$Nu_L = (0.037 {Re_L}^{0.8} - 871) Pr^{1/3}$$

[8 marks]

(c) In part (b), which of the following situations will increase the heat transfer more?

(i) Double the roof area to 2 *m* by 2 *m*, or

(ii) Double the vehicle velocity to 20 *km/h*.

Support your answers with appropriate calculations.

[8 marks]

Note: Take the air properties from the below table.

T (K)	c_p (kJ/kg·K)	μ (kg/m·s)	k (kW/m·K)	ρ (kg/m^3)
300	1.0049	1.846×10^{-5}	2.624×10^{-5}	1.177
400	1.0135	2.286×10^{-5}	3.365×10^{-5}	0.8824
500	1.0295	2.670×10^{-5}	4.041×10^{-5}	0.7060
600	1.0511	3.017×10^{-5}	4.661×10^{-5}	0.5883

Continued...

Question 4

(a) Derive the temperature distribution in an infinitely long uniform cross-section fin and show that the result is

$$T - T_\infty = (T_b - T_\infty)\exp(-mx),$$

where T_b is the base temperature, T_∞ is the surrounding temperature, and $m^2 = hP/kA_c$. All other symbols have their usual meanings in fin analysis. You may assume the fin equation as

$$\frac{d^2T}{dx^2} - m^2(T - T_\infty) = 0$$

[10 marks]

(b) Consider a fin design with a long circular aluminium rod attached at one end to a heated wall to cool the wall by convection to a cold fluid. Using results from (a) or otherwise, obtain an expression for the heat transfer out of this fin. Then, answer the following:

(i) If the diameter of the rod is tripled, by how much would the rate of heat removal change? As an engineer, would you recommend this change in diameter?

(ii) If a copper rod of the same diameter is used instead of the aluminium rod, by how much would the rate of heat transfer change? As an engineer, would you recommend this change in material?

[15 marks]

Note: The thermal conductivities of aluminium and copper may be taken as 240 $W/m\cdot K$ and 400 $W/m\cdot K$, respectively.

End of Paper